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**AIR BAFFLE FOR MANAGING COOLING AIR
RE-CIRCULATION IN AN
ELECTRONIC SYSTEM**

Christopher G. Malone
9604 Drambuie Court
Loomis, CA 95650
Citizenship: Canada

Glenn C. Simon
10085 Snowy Owl Way
Auburn, CA 95603
Citizenship: USA

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Glenn C. Simon

BACKGROUND OF THE INVENTION

[0001] Electronic systems and equipment such as computer systems, network interfaces, storage systems, and telecommunications equipment are commonly enclosed within a cabinet or housing for support, physical security, and efficient usage of space. Electronic equipment contained within the enclosure generates a significant amount of heat. Thermal damage may occur to the electronic equipment unless the heat is removed.

[0002] Low-profile computer system installations present significant thermal management difficulties. For example, Electronics Industry Association (EIA) standard racks are commonly used to house electronic equipment. In relatively large systems, for example 2U or larger where "U" is the measuring unit for racks and rack-mountable components with $1U = 1.75"$ or 44.45mm, most cooling air enters through the front of the enclosure and exits through the rear. For low-profile systems, the enclosure front is significantly blocked by hard drives and media devices. The rear is blocked by power supplies and input/output (I/O) connectors. To lower air flow resistance through the enclosure and enhance cooling, typical 1U and 2U servers use a perforation on the top of the enclosure to supply cooling air and to vent heated exhaust. In a rack fully loaded with standard electronic equipment 1U and 2U devices, such as servers, computers, I/O equipment, and the like, a small clearance is interposed between adjacent stacked devices. For example, in some systems approximately 0.050 inches of clearance separates the devices. The small space between systems permits fresh air from the room to enter near the front of the enclosure and warmed air to exhaust near the rear through separate perforation patterns in the enclosure. However, an unimpeded and direct airflow path exists between the enclosure inlet and exit allowing hot exhaust air to re-circulate from

the devices to the inlet vent, a problem that is exacerbated by cable blockage of airflow exiting the rear of the enclosure. Re-circulation of heated air can create thermal difficulties that may result in system overheating and failure.

[0003] Re-circulation of heated air can impact performance of electronic equipment. If airflow patterns allow re-usage of air that is previously heated by electronic equipment, attempts to cool electronic equipment can fail and less effective heat transfer from the equipment to the cooling airflow can result. In some circumstances insufficient heat transfer can take place and the equipment may overheat and potentially sustain thermal damage.

SUMMARY

[0004] What are desired are an apparatus and operating method that reduce or eliminate re-circulation of heated exhaust air from an electronic device.

[0005] In accordance with various embodiments of an airflow management apparatus for usage in an electronic system, a flexible air baffle mounts on a chassis of an electronic device in an arrangement that obstructs air flow between an air inlet vent and an air exhaust vent of the electronic device. The flexible air baffle has a thickness that extends across a gap to contact an adjacent vertically-stacked electronic device.

[0006] According to other embodiments, an electronic device comprises an electronic system and a chassis enclosing the electronic system. The chassis has substantially planar upper and lower surfaces and extends from a first end to a second end. The electronic device further comprises an air inlet vent formed in the upper surface proximal to the first end, an exhaust vent formed in the upper surface proximal to the second end, and a flexible air baffle. The flexible air baffle is mounted on the chassis in an arrangement that obstructs air flow between the air inlet vent and the exhaust vent. The flexible air baffle has a thickness that extends across a gap to contact an adjacent surface above the chassis.

[0007] According to further embodiments, a system comprises a rack cabinet capable of holding a plurality of stacked electronic devices, an air inlet and exit coupled to mutually opposing sides of the cabinet, a plurality of slots contained within the cabinet and capable of securing the stacked electronic devices, and at least one electronic device inserted into the slots. The individual electronic devices have substantially planar upper and lower surfaces, an air inlet vent formed in the upper surface proximal to the air inlet cabinet side, and an exhaust vent formed in the upper surface proximal to the exit cabinet end. The system further comprises at least one flexible air baffle. The individual baffles are mounted on the upper surface of an associated electronic device in an arrangement that obstructs air flow between the air inlet vent and the exhaust vent. The flexible air baffle has a thickness that extends across a gap to contact an adjacent surface above the upper surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments of the invention relating to both structure and method of operation, may best be understood by referring to the following description and accompanying drawings.

[0009] **FIGURES 1A, 1B, 1C, 1D, and 1E** are multiple perspective pictorial diagrams illustrating embodiments of an airflow management apparatus for usage in an electronic system.

[0010] **FIGURE 2** is a schematic pictorial diagram showing an embodiment of the flexible air baffle.

[0011] **FIGURE 3** is a perspective pictorial diagram that illustrates an embodiment of an electronic device including a flexible air baffle for air flow management.

[0012] **FIGURE 4** is a pictorial perspective diagram showing an example of a server that is commonly used in multiple-server deployments.

[0013] **FIGURE 5** is a front perspective pictorial diagram illustrating multiple vertically-stacked electronic devices.

[0014] **FIGURES 6A and 6B** are frontal pictorial views showing different embodiments of systems capable of holding a plurality of stacked electronic devices.

[0015] **FIGURE 7** is a frontal pictorial view showing an embodiment of a system that uses one or more slot fillers to oppose re-circulation.

[0016] **FIGURES 8A and 8B** are a pair of perspective pictorial diagrams showing examples of cabinets that can be used in system embodiments using one or more flexible air baffles for air flow management.

DETAILED DESCRIPTION

[0017] In a system with a fully loaded cabinet or rack, each rack-mounted device in the rack is adjacent to an overlying device or surface. A baffle can be mounted upon the chassis of an electronic device to obstruct air flow in the space between inlet and exhaust vents on the surface of the chassis. The baffle is typically flexible, for example manufactured from materials such as closed-cell foam rubber, and can extend vertically to make contact with the overlying device or other overlying surface. Flexibility of the baffle allows compliance to account for variation, or tolerance, of the gap dimension between devices and surfaces.

[0018] The flexible air baffle contacts the underside of the overlying surface, either of an electronic device mounted directly above, or other planar surface, creating an obstruction between the inlet and exhaust vents of the electronic device. The obstruction ensures that air entering the inlet vent is from the front of the rack, preventing re-circulation of hot exhaust air from the exhaust to the inlet.

[0019] Referring to **FIGURES 1A, 1B, 1C, 1D, and 1E**, multiple perspective pictorial diagrams illustrate embodiments of an airflow management apparatus **100** for usage in an electronic system. A flexible air baffle **102** mounts on a chassis **104** of an electronic device **106** in an arrangement that obstructs air flow between an air inlet vent **108** and an air exhaust vent **110** of the electronic device **106**.

[0020] Referring to **FIGURE 2** in combination with **FIGURES 1A, 1B, 1C, 1D, and 1E**, a schematic pictorial diagram shows an embodiment of the flexible air baffle **102** with a thickness that extends across a gap **200** to contact an adjacent vertically-stacked electronic device **202**. The flexible air baffle **102** is constructed from a compliant material that allows for variation in the gap dimension between adjacent devices **106** and **202**. For example, the flexible air baffle **102** can be constructed from various materials such as closed-cell foam rubber, silicone, reinforced silicone, urethane, urethane foam, polyurethane, foam sealant, butyl rubber, latex, vinyl, compliant metal, reinforced foam, and others. Various rubber products can be used to form the flexible air baffle **102** such as composite, molded, extruded rubbers, neoprene, and the like. In addition to the illustrative shapes, in various embodiments, the flexible air baffle **102** can have different cross-sectional shapes such as a flexible squeegee shape, a thin-walled cross-section, or any other shape that enables compliance with application of a low force.

[0021] In some embodiments, the flexible air baffle **102** can be in the form of molded flexible strips that can be applied to the surface of the device chassis **104** in various suitable geometries. For example, **FIGURE 1A** shows an embodiment of an electronic device **106** with the flexible air baffle **102** having the form of a rectangular dam surrounding the air inlet vent **108** on three sides with one side open to receive cooling air. The three closed sides obstruct airflow beyond the air inlet vent **108**.

[0022] **FIGURE 1B** shows an electronic device embodiment **106** with the flexible air baffle **102** in the form of a semicircle wedge obstructing air flow beyond the air inlet vent **108** and an open side on the diagonal to receive inlet air.

[0023] **FIGURE 1C** shows an electronic device **106** with the flexible air baffle **102** in the form of a line dividing front and rear sections of the electronic device **106** in various examples, the flexible air baffle **102** may be positioned at different selected positions relative to the front and rear of the device **106**. The illustrative flexible air baffle **102** is straight. In other configurations, the baffle can extend in any shape, irregular, curved, straight, or otherwise so long as the baffle obstructs air flow from the air inlet vent **108** to the air exhaust vent **110**.

[0024] **FIGURE 1D** shows the flexible air baffle **102** in a V-shaped or triangular form. The illustrative embodiments merely sample the many geometries that are suitable to manage air flow.

[0025] **FIGURE 1E** shows an embodiment in which the flexible air baffle **102** forms a dam around the air exhaust vent **110**.

[0026] The illustrative flexible air baffles **102** each have a frontal aperture coupling to a frontal inlet air supply via an airflow pathway and otherwise extend in a solid wall to obstruct air flow laterally and rearward.

[0027] In some embodiments, the flexible air baffle **102** further comprises an adhesive layer **204** that firmly secures the flexible air baffle **102** to the electronic device chassis **104**.

[0028] Referring to **FIGURE 3**, a perspective pictorial diagram illustrates an embodiment of an electronic device **300** comprises a chassis **304** and an electronic system **302**, shown as dotted lines, enclosed within the chassis **304**. The chassis **304** has substantially planar upper and lower surfaces and extends from a first end **306** to a second end **308**. The substantially planar surfaces are largely flat and planar, but may have slight variations and imperfections according to common manufacturing and production practices in the industry. The electronic device **300** further comprises an air inlet vent **310** formed in the upper surface proximal to the first end **306**, an exhaust vent **312** formed in the upper surface proximal to the second end **308**, and a flexible air baffle **314**. The flexible air baffle **314** is mounted on the chassis **304** in an arrangement that obstructs air flow between the air inlet vent **310** and the exhaust vent **312**.

[0029] The electronic device **300** can be used in a rack cabinet **316**, illustratively depicted by dashed lines, which can accept a plurality of stacked electronic devices. The cabinet has an air inlet and exit on mutually opposing sides and a plurality of slots capable of securing the stacked electronic devices.

[0030] The electronic device **300** and internal electronic system **302** can be the type of device that performs one or more of various functions. For example the electronic system **302** can be an integrated circuit functioning as a computer or server, signal processor, data processor, storage device, communication device, or the like. For example, **FIGURE 4** is a pictorial perspective diagram showing an example of a server **400** that is commonly used in multiple-server deployments. In a specific embodiment, the illustrative server **400** can have a 1U size and one-way processor capability for low-cost, rack-optimized usage for single function and front-end applications. Many other types of electronic devices **300** and electronic systems **302** may otherwise or additionally be used.

[0031] Referring to **FIGURE 5**, a front perspective pictorial diagram illustrates multiple vertically-stacked electronic devices, shown as devices **502**, **504**, **506**, and **508**, which can be inserted into a rack cabinet. Between each of the devices is a clearance forming an air gap **510**. For example, a common air gap distance may be in the range of about 0.05 inches, although smaller or greater separation often occurs. Clearance between adjacent electronic devices leaves the air flow gap **510** that extends from an air inlet **512** to exit **514**.

[0032] Flexible air baffles **500** can be used to control airflow in an electronic system by encasing multiple electronic devices in a housing having multiple slots for receiving the electronic devices arranged in a stack. The flexible air baffles **500** have a thickness that extends across the gap **510** to contact an adjacent surface above the device chassis. A cooling air stream flow is directed over the plurality of stacked electronic devices from the air inlet **512** to the exit **514**. The flexible air baffles **500** obstruct air flow in the clearance gap **510** so that essentially all cooling air passes through the electronic devices.

[0033] The flexible air baffles **500** are constructed from a compliant material that allows for variation in the gap dimension between the chassis and the adjacent surface.

[0034] In operation, airflow is controlled by providing an electronic device **502**, **504**, **506**, and **508** having substantially planar upper and lower surfaces and extends from a frontal end to a rearward end. The electronic devices have an air inlet vent **516** formed in the upper surface proximal to the frontal end and an exhaust vent **518** formed in the upper surface proximal to the rear end. The electronic device **502**, **504**, **506**, and **508** is inserted a controlled clearance beneath an overlying substantially planar surface, for example the surface formed by an overlying electronic device. The flexible air baffles **500** are flexible structural members that obstruct air flow between the air inlet vent **516** and the exhaust vent **518**. The flexible structural member extends vertically to span the gap between the electronic device upper surface and the overlying substantially planar surface.

[0035] Referring to **FIGURES 6A** and **6B**, two frontal pictorial view show different embodiments of systems **600** comprising a rack cabinet **602** capable of holding a plurality of stacked electronic devices **604**, an air inlet **606** and exit **608** coupled to mutually opposing sides of the cabinet **602**. A plurality of slots is contained within the cabinet **602** and secures the stacked electronic devices **604**. Multiple electronic devices **604** are inserted into the slots. The individual electronic devices **604** have substantially planar upper and lower surfaces, an air inlet vent formed in the upper surface proximal to the air inlet cabinet side, and an exhaust vent formed in the upper surface proximal to the exit cabinet end. The system **600** further comprises flexible air baffles associated with the electronic devices **604**. The baffles are mounted on the upper surface of an associated electronic device **604** in an arrangement that obstructs air flow between the air inlet vent and the exhaust vent of the device **604**. The flexible air baffle has a thickness that extends across a gap to contact an adjacent surface above the upper surface.

[0036] The flexible air baffle mounts on a chassis of an electronic device **604** within the rack **602** that contains the plurality of vertically-stacked electronic devices. Other than the frontal inlet air supply **606** and the rear exhaust vent **608**, the rack **602** is substantially closed. The substantially closed character of the rack **602** relates to a structure that is largely closed from the outside, but is not required to be completely air-tight. At the front of the rack **602**, the flexible air baffle has an aperture coupling to the inlet air supply **606** via an airflow pathway and otherwise extends in a solid wall to obstruct air flow.

[0037] In the illustrative embodiments, the systems **600** are shown containing a plurality of electronic devices **604** filling all of the corresponding slots so that substantially all of the inlet air flow passes through the electronic devices **604** to the exit.

[0038] In operation, the electronic devices **604** are enclosed in the rack **602** or other housing having the air inlet **606** and exit **608** on mutually opposing sides with the housing **602** being otherwise substantially closed. The air inlet **606** supplies a cooling airflow stream to the electronic device air inlet vent and the exit **608** vents exhaust air from the electronic device exhaust vents. Direct airflow, not passing through the electronic devices **604**, from the air inlet to the exit is substantially otherwise obstructed. Substantial obstruction of direct airflow means that airflow in the system **600** nearly all flows through the electronic devices **604** except for a reasonable, limited amount of leaking through gaps between devices. Some direct airflow can occur from inlet **606** to exit **608** in conditions of a vacant slot.

[0039] In some configurations, an electronic device **604** is enclosed in the rack or housing **602** with multiple additional electronic devices **604**, obstructing air flow between the air inlet vent **606** and the exhaust vent **608** using a multiple flexible structural members associated with the electronic devices **604**. The housing **602** can be fully populated with the electronic devices **604** so that substantially all airflow from the housing air inlet **606** to the exit **608** passes through the electronic devices **604**.

[0040] In other arrangements, configuration, and embodiments, fewer than all of the slots within the rack **602** may be populated by electronic devices **604**. Avoidance or elimination of heated exhaust re-circulation from the electronic devices **604** back to the air inlet, and the potential for device over-heating, are desirable. Referring to **FIGURE 7**, a frontal pictorial view shows an embodiment of a system **700** that uses one or more slot fillers **702** to oppose re-circulation. The system **700** has a cabinet or rack **704** with multiple slots. Electronic devices **706** and slot fillers **702** can be inserted into the rack **704** to fill all slots. In the illustrative embodiment, the slot fillers **702** having dimensions that emulate dimensions of an electronic device **706**. The electronic devices **706** and slot fillers **702** fill all of the corresponding slots so that substantially all of the air flow from

the system cool air inlet **708** passes through the electronic devices **706** and airflow gaps overlying the slot fillers **702** to the exit **710**.

[0041] Referring to **FIGURES 8A** and **8B**, a pair of perspective pictorial diagrams show examples of cabinets **800** that can be used in system embodiments using one or more flexible air baffles for air flow management. The illustrative cabinets **800** have a frame **802** and rail **804** design that accepts and supports multiple various electronic devices such as servers, computer systems, storage devices, communication devices, and the like. The frame **802** and rail **804** structure forms a plurality of slots into which the electronic devices can be inserted. The cabinets **800** have fully perforated front **806** and rear **808** doors that supply efficient convection cooling and ventilation, while facilitating visibility. In the embodiments shown in **FIGURES 8A** and **8B**, the air inlet is formed by the perforated front door **806** and the exit formed by the perforated rear door **808**.

[0042] The cabinet **800** has a frontal surface **810** and columns **812** coupled to the frontal surface on lateral ends of the plurality of slots. The front panel of the electronic devices can attach to the columns **812**.

[0043] While the present disclosure describes various embodiments, these embodiments are to be understood as illustrative and do not limit the claim scope. Many variations, modifications, additions and improvements of the described embodiments are possible. For example, those having ordinary skill in the art will readily implement the steps necessary to provide the structures and methods disclosed herein, and will understand that the process parameters, materials, and dimensions are given by way of example only. The parameters, materials, and dimensions can be varied to achieve the desired structure as well as modifications, which are within the scope of the claims. Variations and modifications of the embodiments disclosed herein may also be made while remaining within the scope of the following claims. For example, the specific examples are systems compliant with EIA standards and form factors. The illustrative structures and techniques may be used with systems of any standard and size. Also, the discussion describes contained electronic devices including servers, computer systems, communication equipment, and storage devices. The flexible air baffles can be used in systems using any

type of electronic equipment that can be mounted in racks. The disclosed systems, devices, and methods may be used with any suitable electronic devices.